Adaptive Augmenting Control and Launch Vehicle Adaptive Control Flight Experiments Element

Center Innovation Fund: AFRC CIF Program | Space Technology Mission Directorate (STMD)

ABSTRACT

Researchers at NASA Armstrong are working to further the development of an adaptive augmenting control (AAC) algorithm. The AAC was developed to improve the performance and robustness of NASA's Space Launch System (SLS) during extreme, unanticipated events well outside the rocket's design envelope. The SLS is expected to produce more thrust and deliver more payload to orbit than any other launch vehicle, opening the way to new frontiers of space exploration. The AAC will use sensed data to autonomously adjust to unexpected conditions during flight to ensure that the SLS does not deviate from its trajectory or experience unstable propellant slosh or vehicle flexure.

A series of LVAC flight experiments conducted at Armstrong successfully increased the technology readiness level of an adaptive augmenting control (AAC) algorithm from 5 to 7. To validate the algorithm's effectiveness, researchers installed the prototype AAC flight software into Armstrong's Full-Scale Advanced Systems Testbed (FAST), giving it full authority control over the aircraft's aerodynamic effectors. Armstrong's FAST aircraft then simulated multiple failure scenarios the SLS may experience as it makes its way from the launch pad to booster separation. These tests provided valuable data that both proved the AAC technology and will aid its future development.

ANTICIPATED BENEFITS

To NASA funded missions:

- **Cost-effective**: Enabled the AAC to be evaluated in-flight without having to be launched into space
- **Systematic**: Allowed multiple, repeated tests with different configurations to compare and isolate characteristics of the design

Continued on following page.

NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment (#1)

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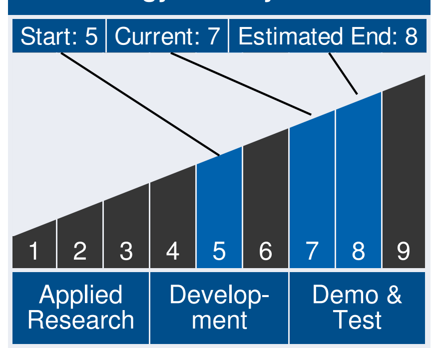
Technology Maturity



To NASA funded missions: ***(cont.)***

- **Unique**: Provided full-scale, high-performance piloted testbed with a proven research flight control system, extensive research instrumentation, data downlink for real-time experiment monitoring, and an experienced flight research team
- **Innovative**: FAST test team proposed and supported additional AAC flight test objectives as the project progressed

To NASA unfunded & planned missions:

The AAC algorithm has applications to civilian, fly-by-wire transports, and high-performance military aircraft. The techniques for conducting the LVAC experiment, and the metrics used in evaluating its results, are applicable to flight research into other adaptive control methods and autonomous systems.

To other government agencies:

The AAC algorithm has applications to civilian, fly-by-wire transports, and high-performance military aircraft. The techniques for conducting the LVAC experiment, and the metrics used in evaluating its results, are applicable to flight research into other adaptive control methods and autonomous systems.

To the commercial space industry:

The AAC algorithm has applications to civilian, fly-by-wire transports, and high-performance military aircraft. The techniques for conducting the LVAC experiment, and the metrics used in evaluating its results, are applicable to flight research into other adaptive control methods and autonomous systems.

To the nation:

The AAC algorithm has applications to civilian, fly-by-wire transports, and high-performance military aircraft. The techniques for conducting the LVAC experiment, and the metrics used in evaluating its results, are applicable to flight research into other adaptive control methods and autonomous systems.

Realized Benefits

1 Success Story

Management Team

Program Manager:
- David Voracek

Principal Investigator:
- Curtis Hanson

Technology Areas

Secondary Technology Area:
Modeling, Simulation, Information Technology and Processing (TA 11)

Other Technology Areas:
- Ground and Launch Systems (TA 13)
- Mission Success (TA 13.4)

DETAILED DESCRIPTION

Researchers at NASA Armstrong are working to further the development of an adaptive augmenting control algorithm (AAC). The AAC was developed to improve the performance and robustness of NASA's Space Launch System (SLS) during extreme, unanticipated events well outside the rocket's design envelope. The SLS is expected to produce more thrust and deliver more payload to orbit than any other launch vehicle, opening the way to new frontiers of space exploration. The AAC will use sensed data to autonomously adjust to unexpected conditions during flight to ensure that the SLS does not deviate from its trajectory or experience unstable propellant slosh or vehicle flexure.

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Work to date: The LVAC experiment included six research flights in late 2013. The FAST aircraft flew trajectories similar to the ones the SLS will follow, and the system was evaluated in a variety of scenarios for up to 70 seconds at a time, matching the SLS dynamics for the majority of its flight from liftoff to solid rocket booster separation. A total of 104 test points were completed, covering 14 simulated failure scenarios and off-nominal events. The controller was evaluated with and without adaptive control for each test case to provide a basis for comparison. In the final flights, two experienced test pilots provided evaluations of interactions between the manual steering mode and the AAC for several of the test cases.

Looking ahead: The flight test data are being used to refine the AAC software and plans for future tests. The first flight of the SLS, with the AAC algorithm enabled, is scheduled for 2018.

NASA Partners: Marshall Space Flight Center, Engineering and Safety Center, and Space Technology Mission Directorate's Game Changing Development Program

Benefits:

- Cost-effective: Enabled the AAC to be evaluated in-flight without having to be launched into space
- Systematic: Allowed multiple, repeated tests with different configurations to compare and isolate characteristics of the design
- Unique: Provided full-scale, high-performance piloted testbed with a proven research flight control system, extensive research instrumentation, data downlink for real-time experiment monitoring, and an experienced flight research team
- Innovative: FAST test team proposed and supported additional AAC flight test objectives as the project progressed

Applications: The AAC algorithm has applications to civilian, fly-by-wire transports, and high-performance military aircraft. The techniques for conducting the LVAC experiment, and the metrics used in evaluating its results, are applicable to flight research into other adaptive control methods and autonomous systems.

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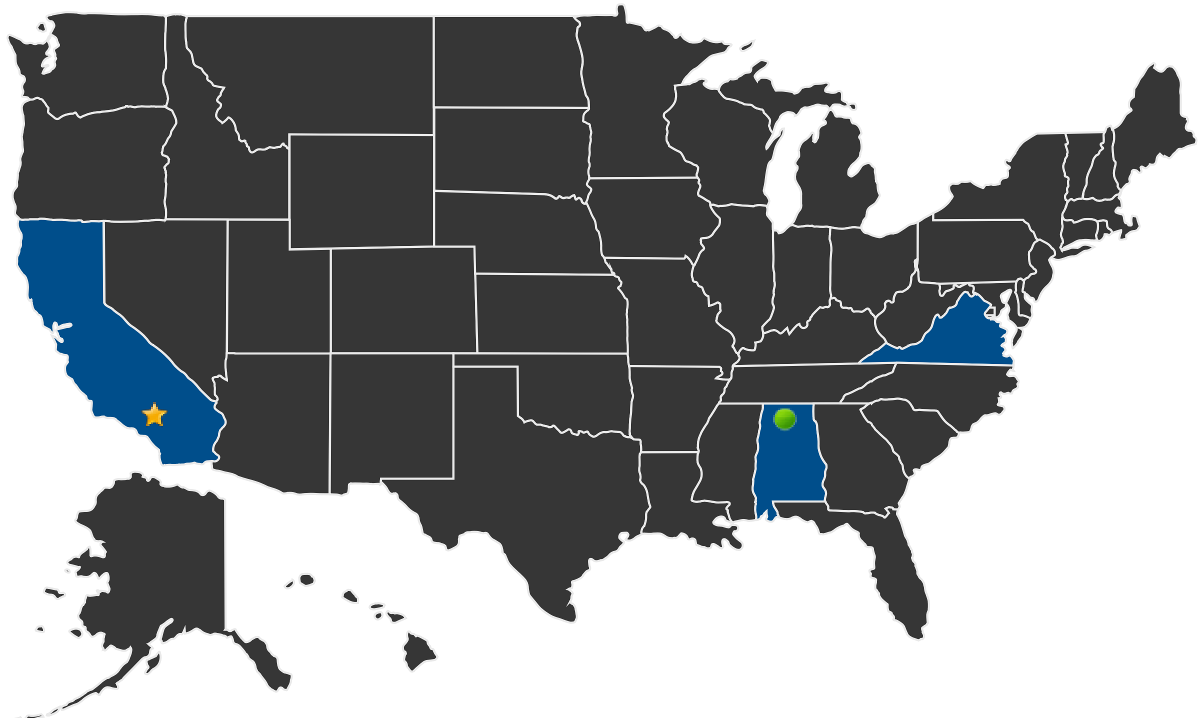
U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Armstrong Flight Research Center

Supporting Centers:

- Marshall Space Flight Center

Other Organizations Performing Work:

- Engineering and Safety Center
- Space Technology Mission Directorate's Game Changing Development Program

LATEST SUCCESS STORY

LVAC Sucess Story

ELEMENT LIBRARY

Success Stories

- LVAC Sucess Story
  - (http://techport.nasa.gov:80/file/16816)

IMAGE GALLERY

NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment (#2)

NASA's Full-Scale Advanced Systems Testbed (FAST) aircraft during LVAC experiment (#3)

DETAILS FOR TECHNOLOGY 1

Technology Title

Adaptive Augmenting Control (AAC) Algorithm

Technology Description

This technology is categorized as firmware for manned spaceflight

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Capabilities Provided

- Cost-effective: Enabled the AAC to be evaluated in-flight without having to be launched into space
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Potential Applications

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